Chapter 19 Quantification of Exposure: Multimedia Monitoring

Table of Contents

19.1 Introduction

As noted earlier, modeling is generally the recommended approach for estimating exposure concentrations for air toxics risk assessments (for both inhalation and other pathways). However, there may be circumstances in which monitoring is requested or recommended for a particular multipathway risk assessment. This chapter provides an overview of multimedia monitoring, including the reasons for monitoring (Section 19.2), planning and implementation issues (Section 19.3), and available monitoring methods (Section 19.4).

19.2 Why Monitor?

The reasons for monitoring for a multipathway risk assessment are identical to those noted earlier for inhalation risk assessments (Chapter 10):

- Measuring existing concentrations of air toxics in specific locations (e.g., soils in a schoolyard) and/or food items (e.g., fish from a lake within the study area) for purposes of developing estimates of exposure;
- Developing or refining values for specific parameters needed by multimedia models;
- Evaluating the predictions of a model in specified circumstances (e.g., estimates of sediment concentrations resulting from deposition and runoff);
- Closing gaps that might be present in existing data (e.g., gaps in emissions inventory); and
- Providing compliance/enforcement information as to whether a given facility or set of sources is meeting regulatory or permit requirements.

Monitoring for Evaluation of Multimedia Modeling

For multipathway risk assessments, monitoring is a valuable tool for evaluating model predictions because multimedia modeling is more complicated and involves more uncertainties than does air quality modeling. When using samples to evaluate model predictions, however, it is important to realize that **monitored concentrations may be greater than model predictions** because sources other than those being modeled may have contributed to the contamination.

19.3 Planning and Implementing Issues

The planning and implementation processes for multipathway risk assessment monitoring programs are similar to those for air monitoring programs discussed in Chapter 10. The planning process involves a step-wise integration of data quality and data sampling and analysis processes that are consistent with the study-specific conceptual model (CM), quality assurance project plan (QAPP), and data quality objectives (DQO) process. Many of the general planning and implementation issues for air monitoring programs also apply to multimedia modeling. Some additional considerations arise because the sampling and analysis program might include soils, surface waters, sediments, fish, meat, vegetables, milk, and other human food items. The scale and scope of monitoring could be much greater (e.g., multiple media could be sampled), and issues specific to ingestion need to be considered (e.g., what parts of plants and animals do people eat?).

- **Monitoring or sampling methods should be appropriate for the compounds and environmental media to be measured**. They must have the sensitivity needed to monitor at the levels likely to be of health and/or regulatory concern.

- **Monitoring sites and frequency of monitoring should be appropriate for the spatial and temporal variation of the chemical being measured and the monitoring objective**. Typically, an exposure location (e.g., a water body, a property, an agricultural field) or source (e.g., milk from cows on a specific farm) is defined for the risk assessment. The monitoring program should be adequate to represent the spatial and temporal variation within the location or source, given the particular measure(s) used to support the risk management decision to be made (e.g., average exposure, maximum exposure). However, several aspects of spatial and temporal variation are unique to air toxics that persist and which also may bioaccumulate. For example:
  - The temporal patterns of releases from sources may be less important because the chemicals may slowly accumulate in media and biota over time;
  - Spatial "hot spots" of contamination may occur (for example, if soils erode and collect in low-lying areas);
  - Chemicals generally accumulate in different tissues at different rates; therefore, concentrations may be higher in certain parts of the plant or animal (which may or may not be the parts that people tend to eat, and vice versa);
  - Certain seasonal effects (e.g., growing season for plants, migratory movements in animals) may be important sources of variation; and
  - Age of the plant or animal being sampled may be important if it takes many months or years for contaminants to reach equilibrium in biological tissues (or if equilibrium is never reached). For example, mercury concentrations in fish tend to be higher in older, larger fish.

- **The monitoring effort should consider the relative contributions of the four main sources of variability in measurements**. As noted in Chapter 10, these are analytical, sampling, temporal, and spatial.

- **Standard operating procedures should be defined and followed** both in the field (during sample collection) and in the laboratory (during sample analysis). These include procedures related to sample collection, sample transport and storage (including prevention of sample degradation), sample analysis, "chain of custody," audits, data validation, and data reporting. These procedures may be quite varied due to the range of possible media and biota that could be sampled.

- **Limits of quantitation or detection should be determined and compared** against relevant decision needs, including health benchmarks and likely environmental levels.

- **Measurement processes should be properly calibrated** to ensure the accuracy of the method.

- **Results must be adequately recorded and archived**. The best monitoring program can be compromised by a failure to keep proper records that can be made part of the public record.

A periodic, random check of the archived records (e.g. computer files) should be made against "hard copies" to ensure the integrity of the process of recording the data.

Soil Depth: Issues for Sampling

The depth over which surface soils are sampled should reflect the type of exposure expected in the study area, the type of receptors expected in the study area, the depth of biological activity and the depth of potential contamination. Careful consideration of the size, shape, and orientation of sampling volume is important since they have an effect on the reported measured contaminant concentration values.(1) Selection of sampling design and methods can be accomplished by use of the Data Quality Objectives (DQO) process discussed in Chapter 6. Additional soil sampling guidance that may be consulted includes EPA's *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies* and *Guidance for Data Usability in Risk Assessment* and *Soil Screening Guidance*, available at: http://www.epa.gov/superfund/programs/risk/tooltrad.htm#dbhh.(2)

19.4 Monitoring and Sampling Methods, Technologies and Costs

19.4.1 Method Selection

Method selection for sample collection and analysis programs that are applicable to multipathway human health risk assessments are dependent on numerous aspects of the project. Factors such as media, sample types, sample program designs, lead regulatory authority, and concentration ranges of concern all can impact the selection of the appropriate methods. While it is not possible for this chapter to review all of the monitoring methods available for this broad range of applications, several of the more important factors that generally influence decisions on methods selected are discussed below.

The primary determining factor in selection of sample collection and analysis methodologies is the sample media to be evaluated. Exhibit 19-1 presents several examples of the types of media that might be sampled for a multipathway human health risk assessment.[a] Other factors that affect selection of sample collection methods are sample type and sample program design. Specific factors in selection of sample collection methods may also be construction material of the sampling devices, its design, decontamination, and proper use, site-specific conditions, relative cost, and data quality limitations.

Sample collection methods may be categorized by sample type as discussed in Chapter 10. However, the distinction is not always clear (e.g., a single fish tissue sample might be considered a grab sample because it is collected at a single location and time; however, because the contaminant concentrations in its tissues accumulate over time, the sample could also be considered a time-integrated sample). The more common types of samples used for non-air sampling are provided below:

- **Grab samples** (also known as discrete samples) are collected at a specific location (and generally instantaneous) time. Any technique where the sampling container is filled to represent a snapshot of the concentration of target contaminants at a single specific time is

[a] Air sampling also may be conducted; however, that is discussed in Chapter 10.

considered a grab sample. Where the population to be represented is demonstrated to be homogenous or consistent, grab samples provide the maximum information.

- **Time-integrated samples** are collected at a single location but over an extended period of time. Similar to grab samples, analysis of time-integrated samples provides a snapshot of that range of time and location as a single value. Only the total pollutant collected is measured, and so only the average concentration during the sampling period can be determined.

Exhibit 19-1. Examples of Environmental Media that May be Sampled for Multipathway Human Health Risk Assessment [(a)]

Medium	Comments
Surface Water	Generally sampled only if used as a drinking water source
Soils	Generally sampled within the top few inches of the surface, where ingestion exposure or erosion may occur, but other considerations may require a different soil sampling depth
Sediments	Generally sampled to support assessments of bioaccumulation in aquatic systems (in more rare instances, sediments might support a dermal assessment of exposure to the sediments themselves)
Fish	Generally focused on species and parts of the fish that people eat (although this may vary regionally; e.g., some native cultures may routinely eat the entire fish)
Vegetables and other crops	Generally focused on the plants and parts of plants that people eat and/or are fed to livestock
Dairy products and other foods	Generally focuses on milk and other dairy products; eggs and meat are also sometimes evaluated

[(a)] Note that this list is not exhaustive; additional types of samples might be appropriate for a given risk assessment.

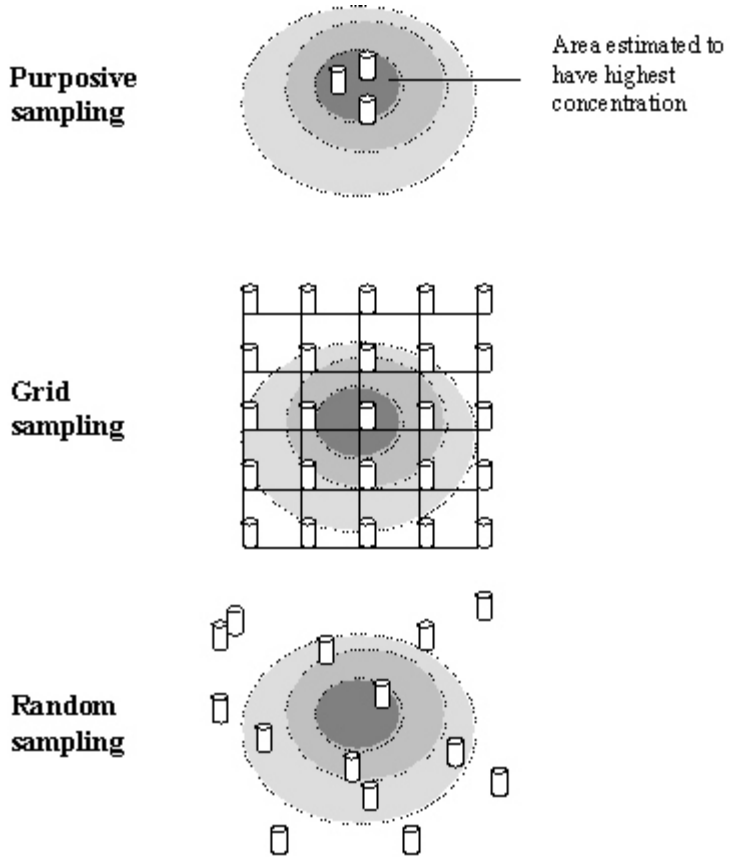
- **Composite samples** represent combinations of discrete samples, which may be collected either at different times or from different locations, that are combined into a single sample for analysis. Composite samples can be helpful when the amount of material that can be obtained from a single sample is very small (e.g., fish tissue), and the analytical quantitation limit can be lowered if the sample mass is increased (e.g., by combining multiple samples into a single composite sample for analysis). Composite samples also can be helpful when resources for laboratory analysis are limited, as they provide an estimate of average concentration across multiple samples, with the analysis cost of only one sample. The greatest drawback to composite samples is that they do not allow for an understanding of the variation in concentration values among the individual samples collected.

- **Continuous samples** provide essentially real-time measurements over time from a single, specific location. Continuous measurements typically involve real-time measurements, because samples cannot be practically collected to provide true continuous data. Continuous monitoring data frequently are evaluated as a function of concentration over the time period

analyzed. Depending on the application, maximum, median, time-weighted average, or distribution curves may be applied to reduce the large amount of results obtained from true continuous data to usable results which can be compared to decision criteria.

Sample collection methods may also be determined by the sample collection design methodology (Exhibit 19-2). Sample design impacts method selection often by determining the number of samples being collected.

Exhibit 19-2. Common Types of Sampling



Purposive sampling focuses the sampling effort in specific locations (in this example, the area estimated to have the highest concentration). Grid sampling consists of regularly-spaced samples in a predetermined grid. Random sampling consists of samples in locations selected by chance.

- **Purposive** sampling involves focused sample collection based on previous knowledge of release event locations. Purposive (also called biased) sampling is named such because the person taking the sample willfully takes that sample at a time or place where, based on prior knowledge, it is expected that concentrations will generally be biased high. Purposive sampling may be desired in programs looking to verify expected model results. Purposive sampling often targets maximum contaminant conditions to evaluate maximally impacted areas. However, it may be used for reasons such as targeting specific species to calibrate bioaccumulation models or defining the spatial extent of contamination.

- **Systematic** sampling consists of collecting samples at locations and times according to specific patterns (e.g., grid sampling). Systematic sampling may use previous knowledge to set frequency, density, or coverage of sampling.

- **Random** sampling involves collecting samples from locations in a manner such that each location has an equal probability of being sampled and analyzed. Random sample collection designs are an important aspect of certain statistical data evaluations.

The factors which primarily affect selection of preparation and analysis methods include target contaminants, required reporting limits (i.e., concentration range of decision criteria), number of samples, data quality limitations, method/instrument portability, previous data comparability, acceptance/approval by regulators and stakeholders, and relative cost and availability.

- **Target contaminants**. The specific contaminants being sampled may have a significant impact on both budget and overall approach. For example, sampling and analytical procedures for metals are different than those for organic chemicals. Careful evaluation before inclusion of unwarranted parameters and establishment of a procedure for identification and removal of chemicals of potential concern (COPCs) is critical to an effective monitoring program.

- **Required reporting limits**. Assessors should select analytical methods so that the reporting limits (usually the estimated quantitation limits) are less than the effects concentrations of interest. If the assessor does not select an adequately sensitive analytical method, the quantitation limit for a given chemical could exceed the chemical's effects benchmark concentration of interest; in that case, monitoring information would not provide meaningful input to the risk assessment.

- **Number of samples**. A sampling program that involves screening-level assessment of a large number of samples may drive selection of certain methods for the bulk of samples in order to allocate limited resources. In the opposite case, determination of low heterogeneity of sample media, and extremely low risk-based concentrations of interest as decision criteria may require fewer samples and more highly sophisticated methodologies.

- **Data quality limitations**. High data quality requirements imposed by high uncertainty or other factors may influence the choice of sampling methods such as procedures that are more stringent and more costly than usual procedures.

- **Method/instrument portability**. In-field or on-site analysis has begun to replace laboratory-based analysis in many monitoring programs. Certain preparation and analysis methodologies are more portable than others, in part because of the sensitivity of the instrumentation. However, considerable expertise in sampling and analysis is needed to decide whether in-field or laboratory-based analysis is appropriate for the study.

- **Previous data comparability**. Previous data sets can affect selection of appropriate methods. All other factors being equal, data comparability goals and objectives are more easily met by use of consistent methods.

- **Stakeholder input**. Stakeholder preferences may influence method selection.

- **Relative Cost/Availability**. The reality of limited resources often impacts method selection. Certain monitoring methods are commonly performed and available at numerous laboratories or by readily available field instrumentation. Other more obscure methods may better meet the needs of the project but are only available from highly specialized laboratories. In addition to cost impact, low availability of some specific monitoring methods can impact data quality due to lack of practice, market competition, appropriate standards, or certifications.

19.4.2 Available Methods

Hundreds of specific sampling, test, analysis, and quality assurance methods and procedures exist for soil, water, sediment, and biota. The list of available methods changes frequently as new methods are introduced and older methods are retired. It is not possible for this chapter to review all of the monitoring methods available. Instead, this section provides an overview of several key EPA resources and provides a listing of web sites that serve as sources of additional information. Key EPA resources include the *EPA Test Methods Index*; the Contract Laboratory Program (CLP); and the Fish and Wildlife Advisories Program.

- ***EPA Test Methods Index*** (http://www.epa.gov/epahome/Standards.html). EPA has developed hundreds of specific sampling, test, analysis, and quality assurance methods and procedures. In response to frequent requests for agency test methods, Region 1 Library staff developed a methods index as a tool to help locate copies. Confirming that there was no single volume containing all agency methods and no comprehensive list of them, the project commenced and in 1988 printed the first *EPA Test Methods Index*.[3] It has been updated periodically to reflect new procedures and revoked methods, and the current edition includes about 1,600 method references. The index includes only EPA methods, and its primary goal remains as a reference tool to identify a source from which the actual method can be obtained, either free or for a fee.

- **EPA Contract Laboratory Program**. The Contract Laboratory Program (CLP) is a national network of EPA personnel, commercial laboratories, and support contractors whose fundamental mission is to provide data of known and documented quality, primarily for the Superfund program (http://www.epa.gov/superfund/programs/clp/about.htm). The Analytical Operations/Data Quality Center (AOC) provides several tools to assist CLP clients, laboratories, and samplers (http://www.epa.gov/superfund/programs/clp/tools.htm). These tools were designed to use the Internet to facilitate many of the essential functions of the CLP.

Available Guidance from EPA's Contract Laboratory Program

Contract Laboratory Program National Functional Guidelines for Low Concentration Organic Data Review EPA-540-R-00-006 June 2001

Contract Laboratory Program National Functional Guidelines for Organic Data Review EPA-540/R-99-008 (PB99-963506) October 1999

Contract Laboratory Program National Functional Guidelines for Inorganic Data Review EPA 540-R-01-008 July 2002

Contract Laboratory Program National Functional Guidelines for Chlorinated Dioxin/Furan Data Review EPA-540-R-02-003 August 2002

Contract Laboratory Program Guidance for Field Samplers (Draft-Final) EPA-540-R-00-003 April 2003

This information, as well as methodology information is available from the CLP at: http://www.epa.gov/superfund/programs/clp/services.htm

- **EPA's Fish and Wildlife Advisories Program** (http://www.epa.gov/waterscience/fish/). EPA's Office of Science and Technology provides technical and outreach material that support efforts by state, local, and tribal (S/L/T) governments to protect their residents from the health risks of consuming contaminated noncommercially caught fish. S/L/T governments do this by issuing consumption advisories for the general population as well as for specific vulnerable sub-populations. These advisories tell the public when high concentrations of chemical contaminants have been found in local fish. They also include recommendations to limit or avoid eating certain fish species from specific water bodies or water body types. The program also provides *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (http://www.epa.gov/waterscience/fish/guidance.html), a set of four volumes that provides guidance for assessing health risks associated with the consumption of chemically contaminated non-commercial fish and wildlife. The set includes Third Editions of Volume 1: *Fish Sampling and Analysis* and Volume 2: *Risk Assessment and Fish Consumption Limits*.

Exhibit 19-3 provides links to information on specific sampling and analysis methods, summarized from key EPA compendia of methods. Methods are divided into four categories (General, Analytical Method Index, Sample Collection, and Quality Assurance). Keywords are added to help readers get to the area they are concerned with. Additional effort may be required to "drill into" each site to view the relevant information. These links generally are limited to government sites. Some non-EPA sites are included (e.g., Occupational Safety and Health Administration (OSHA), National Institute of Standards and Technology (NIST), and National Institute for Occupational Safety and Health (NIOSH)) to help fill specific information gaps.

Exhibit 19-3. Sources for Information on Specific Sampling and Analysis Methods	
Keywords	**Description and URL Link**
General References	
Sample collection, analysis method, criteria, water	General EPA Water page with links to analytical methods, sampling guidance, and criteria for assessment of contamination. http://www.epa.gov/waterscience/
Analysis methods	EPA' s Office of Ground Water and Drinking Water (OGWDW) links to analysis methods. http://www.epa.gov/OGWDW/methods/methods.html
Sample collection, analysis methods, reference	NIOSH pocket guide to chemical hazards contains information by analyte which can support field sample collection, analysis, and determination of relevant criteria. http://www.cdc.gov/niosh/npg/npg.html
Sample collection, analysis methods, reference	NIST web book contains information by analyte which can support field sample collection, analysis, and basic chemical parameters from thermodynamic constants to reference mass spectra. http://webbook.nist.gov/chemistry/
Sample collection, analysis methods, reference	General EPA environmental test methods and guidelines page with numerous links to other areas of information throughout EPA web sites. http://www.epa.gov/epahome/Standards.html
Analysis Method Index	
Analysis methods, sample collection	Region I list of methods available as hardcopy and partial links to analysis methods. http://www.epa.gov/epahome/index/
Analysis methods, sample collection	Searchable online database of analysis methods. NEMI is a project of the National Methods and Data Comparability Board, a partnership of water quality experts from Federal agencies, States, Tribes, municipalities, industry, and private organizations supported by EPA and the U.S. Geological Survey. http://www.nemi.gov
Analysis methods, sample collection	National Exposure Research Laboratory (NERL) formerly EMSL, Manual of Manuals links to information about analysis methods; summaries and ordering information for eight laboratory analytical chemistry methods manuals published by the former Environmental Monitoring Systems Laboratory-Cincinnati (EMSL-Cincinnati) between 1988 and 1995. http://www.epa.gov/nerlcwww/methmans.html
Analysis Methods	
Analysis methods, water	EPA's Office of Water link to analysis methods. Laboratory analytical methods that are used by industries and municipalities to analyze the chemical and biological components of wastewater, drinking water, sediment, and other environmental samples that are required by regulations under the authority of the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). http://www.epa.gov/waterscience/methods/
Analysis methods, water, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 624, 625, 1624, 1625	Methods for organic chemical analysis under the authority of the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). http://www.epa.gov/ostwater/methods/guide/methods.html

Exhibit 19-3. Sources for Information on Specific Sampling and Analysis Methods	
Keywords	**Description and URL Link**
Analysis methods, drinking water	Recent drinking water methods from EPA's Office of Research and Development, National Exposure Research Laboratory (NERL), formerly the Environmental Monitoring Systems Laboratory (EMSL). http://www.epa.gov/nerlcwww/ordmeth.htm
Organic, analysis methods, drinking water	Organic method index with hyperlink to method by analyte in drinking water as maintained by Office of Ground Water and Drinking Water. http://www.epa.gov/OGWDW/methods/orch_tbl.html
Inorganic, metal, analysis methods, drinking water	Inorganic and metal analysis methods in drinking water as maintained by Office of Ground Water and Drinking Water. http://www.epa.gov/OGWDW/methods/inch_tbl.html
Analysis methods, drinking water, radionuclides	Radionuclides in drinking water as maintained by Office of Ground Water and Drinking Water. http://www.epa.gov/OGWDW/methods/rads.html (EPA) http://www.epa.gov/OGWDW/methods/indrads.html (non-EPA)
Analysis methods, drinking water,	Approved methods for unregulated contaminants in drinking water as maintained by Office of Ground Water and Drinking Water. http://www.epa.gov/OGWDW/methods/unregtbl.html
Analysis methods, drinking water,	Secondary contaminants in drinking water as maintained by Office of Ground Water and Drinking Water. http://www.epa.gov/OGWDW/methods/2nd_tbl.html
Analysis methods, immunoassay	Region 1 guidance on immunoassay methods. http://www.epa.gov/region1/measure/ia/iaguide.html
Analysis methods, CLP, organic, dioxin, inorganic, water, soil	Contract Laboratory Program (CLP) methods for organics, inorganics, and dioxins/furans. http://www.epa.gov/superfund/programs/clp/methods.htm
Analysis methods, air	EPA Emissions Measurement Center (EMC) for methods related to determination of airborne pollutants. http://www.epa.gov/ttn/emc/
Analysis methods, pesticide, soil, water	EPA' Office of Pesticide Programs (OPP) database of environmental chemistry, residual, and antimicrobial analysis methods. http://www.epa.gov/oppbead1/methods/
Analysis methods, water, soil, sediment, waste, air	EPA's OSWER provides online updated SW-846 waste sampling and analysis methods manual which is the source of many related methods used in environmental sampling and analysis. http://www.epa.gov/epaoswer/hazwaste/test/main.htm
Sample collection, analysis methods, air	Occupational Safety and Health index of sampling and analysis methods alphabetically by parameter and general information on selection of methods and laboratories. http://www.osha-slc.gov/dts/sltc/methods/index.html
Sample collection, analysis methods, air	EPA's Organic (TO) Compendium of methods for air toxics and EPA's Inorganic (IO) Compendium methods. http://www.epa.gov/ttn/amtic/airtox.html
Sample Collection	
Sample collection, analysis, fish, shellfish, biota	Methods for sampling and analyzing contaminants in fish and shellfish tissue. http://www.epa.gov/waterscience/fishadvice/volume1/index.html

Exhibit 19-3. Sources for Information on Specific Sampling and Analysis Methods	
Keywords	**Description and URL Link**
Sample collection	Current manuals and protocols prepared by NERL-Cincinnati scientists. NERL is the EPA's scientific lead for the following stream and source monitoring indicators: fish, macroinvertebrates, periphyton, zooplankton, functional ecosystem indicators, water and sediment toxicity and fish tissue contaminants. As part of their indicator lead responsibilities NERL-Cincinnati scientists prepare and update field and laboratory protocol and methods manuals for these indicators. http://www.epa.gov/nerleerd/methman.htm
Sample collection, monitoring wells, low stress	Guidance for RCRA/Superfund groundwater sample collection methodologies and the logical process for determining an approach fit to site specifics. http://www.epa.gov/tio/tsp/download/gw_sampling_guide.pdf
Sample collection, monitoring wells, low stress	Generally well accepted low stress (low flow) ground water sample collection guidance from EPA Region I. Several versions exist across EPA regions and within other governmental and State guidelines. http://www.epa.gov/region1/measure/well/wellmon.html
Sample collection, field analysis	EPA Environmental Response Team provides numerous sampling and field analysis Standard Operating Procedures (SOPs) often encountered in environmental responses including otherwise atypical sample collections SOPs such as drum, wipe, and waste pile sampling techniques. http://www.ertresponse.com/sops.asp
Sample collection, field analysis, program design	EPA's Office of Technology Innovation provides a web site with information on proper sampling program design, QA/QC concerns, and use of field methodologies to expedite information collection without loss of data quality. http://clu-in.org
Quality Assurance	
Quality assurance	EPA Agency-wide quality system documents for EPA and non-EPA organizations plus general guidance. Documents are available as PDFs. http://www.epa.gov/quality/qa_docs.html
Quality assurance	Region I guidance includes quality assurance documents. http://www.epa.gov/region1/lab/qa/qualsys.html

References

1. U.S. Environmental Protection Agency. 2000. *Draft Ecological Soil Screening Level Guidance*. Office of Emergency and Remedial Response. July 10, 2000.

2. U.S. Environmental Protection Agency 1992. *Guidance for Data Useability in Risk Assessment (Part A)*. Office of Emergency and Remedial Response, Washington, D.C., April 1992. Publication 9285.7-09A, PB92-963356. Available at: http://www.epa.gov/superfund/programs/risk/datause/parta.htm

   U.S. Environmental Protection Agency 1992. *Preparation of Soil Sampling Protocols: Sampling Techniques and Strategies*. Office of Research and Development. EPA/600/R-92/128. Available at: http://www.epa.gov/superfund/programs/risk/tooltrad.htm#dbh

   U.S. Environmental Protection Agency 1996. *Soil Screening Guidance: User's Guide*. Office of Solid Waste and Emergency Response. Washington, D.C., July 1996. EPA540/R-96/018. See especially Attachment B, *Soil Screening DQOs for Surface Soils and Subsurface Soils*. Available at: http://www.epa.gov/superfund/resources/soil/index.htm#user

   U.S. Environmental Protection Agency. 2002. *Supplemental Guidance For Developing Soil Screening Levels for Superfund Sites*. Office of Solid Waste and Emergency Response, Washington, D.C., December 2002. OSWER 9355.4-24. Available at: http://www.epa.gov/superfund/programs/risk/tooltrad.htm#dbh

3. U.S. Environmental Protection Agency. 1988. *EPA Test Methods Index*. EPA 901/388/001.